Quantitative Determination of Formaldehyde and Ammonium Thioglycolate (ATG) Allergen Levels as "Quality Markers" in Commercial Synthetic Braiding Hair Sold in Selected Cosmetic Beauty Shops in Kisii Town, Kenya

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Abstract

The current study investigated the quality of commercial synthetic braiding hair sold to consumers in a classical African beauty shop by determining the presence of Formaldehyde and Ammonium Thioglycolate (ATG) allergens present. These hair extensions often produced from traces of human hair, natural fibers or synthetic fibers lead to chemical exposure to consumers increasing public health concerns. Targeted analysis (TA) was used to analyse the chemical composition of commonly used commercial Synthetic braiding hair. Allergic reactions that include scalp irritation and dandruffs have been reported among consumers in frequent users. The model compounds in this study, i.e. Formaldehyde and Ammonium Thioglycolate have been specifically associated with various skin conditions. A total of 6 samples i.e. (3) samples of the same braiding hair samples were obtained from atleast two cosmetic beauty shops in Kisii town, Kenya. The samples were analysed in the laboratory first by cutting and dividing the elongated samples into (3) parts; (i) center (ii) outer (iii) Ends. Separate pieces of the cut braids from all the brands were cut into small pieces, placed into (18) separate test tubes securely inserted into (3) test tube stands. Qualitative visual determination of the presence of Formaldehyde and Ammonium Thioglycolate in the samples in each test tube was achieved using the silver mirror test (Tollens' reagent) and silver nitrate solution. Quantitative determination was done using chemical concentration in the samples was determined by UV-Vis Spectroscopy (SHIMADZU 1800) at λ= 353 nm. The results were analysed using qualitative and quantitative methods that included observation and interpretation, while quantitative data was analyzed using correlation analysis and data visualization techniques. This led to the conclusion of the absence of Ammonium Thioglycolate (ATG) in the sample's alpha and Omega. For both alpha and omega samples, the appearance of s silver mirror in the test tube confirmed the presence of formaldehyde. The average concentration of formaldehyde (ppm) was determined as follows: -[alpha = 80 ppm; omega=50 ppm)]. Hair braiding sections revealed the following formaldehyde loadings as follows :-[((alpha)- center=80 ppm; outer layer=90 ppm; Ends/edges=70 ppm) ;(Omega)- center=50 ppm; outer layer 70 ppm; Ends/edges= 40 ppm))]. The results indicate the alpha brand is of better quality due to lower formaldehyde levels. The results show increased presence of formaldehyde at the outer layer of the hair braiding samples while the ends/edges showed decreased levels. The current study concludes that both alpha and omega hair braiding samples did not contained any traces of ammonium thioglycolate result but were contaminated with formaldehyde.

Keywords: *Quantitative Determination, Synthetic Braiding Hair, Formaldehyde, Ammonium Thioglycolate, Allergens*

Introduction

Women frequently use synthetic braids to style their hair, especially those with afro-textured hair[1]. However, wearing synthetic braids has been linked to scalp itchiness, which can be irritating and uncomfortable. This itchiness is due to some chemicals in the synthetic braids that could irritate the scalp of the head[1]. Synthetic braids are a common extension made from a variety of synthetic fibers, including kanekalon, toyokalon, and jumbo braid. Chemical ingredients employed in braid manufacture may improve their aesthetic appeal and useful qualities. Synthetic braids are made in some phases, and at each one, particular chemicals are added for a specific purpose. A host of dangerous chemicals, including carcinogens, lead, and volatile organic compounds (VOCs), have been found in some of the most popular synthetic hair brands used in braided styles [2].

In a case study [3] consumer reports tested ten synthetic braiding hair products and found toxins in all ten. For example, three products contained benzene, a carcinogen that has been linked with acute myeloid leukemia. Nine out of ten products contained unsafe levels of lead, which in adults can cause kidney damage, cardiovascular problems, reproductive damage, and brain damage, and in children can lead to brain and nervous system damage, learning disabilities, behavioral problems, and developmental delays.

For people who wear the synthetic braids, the chemicals are "sitting on your scalp and be dermally absorbed. [They] can be inhaled. Somebody touches their hair and they eat something, it's hand-to-mouth, so it can enter the body that way as well. The greater the exposure to products that contain formaldehyde in terms of both length of time and concentration, the higher the potential health risks [4]. Individuals who have experienced formaldehyde exposure have described reactions such as eye problems or irritation, nervous system problems (for example, headaches and dizziness), respiratory tract problems (sore or scratchy throat, cough, wheezing), nausea, chest pain, vomiting, and rashes. Chronic effects associated with formaldehyde can include an increased prevalence of headaches, asthma, contact dermatitis (a red, itchy rash caused by direct contact with a substance or an allergic reaction to it as a result of sensitization) and possibly cancer [5].

Industrial Production of Synthetic Braiding Hair

This comprehensive approach aims to elucidate the potential health risks associated with these common hair extensions. The primary raw ingredients used to make synthetic braids are typically petroleum-based polymers like Polyethylene Terephthalate (PET) and Polypropylene (PP). Several additives, including stabilizers, plasticizers, and colorants, may be used to modify the properties of the polymer as it is being produced. The consistency of color, suppleness, and durability can all be enhanced by these additions. Polymer pellets are melted and extruded via a spinneret or die to create continuous filaments. The molten polymer is formed using high temperatures and mechanical forces during the extrusion process. Chemical chemicals: During the extrusion step, chemicals including antioxidants, UV stabilizers, and sliding agents may be added to the braids to enhance their processing and performance characteristics. These additives increase surface quality, reduce friction, and provide resistance to environmental impacts.

Chemical Additives in the Cosmetic and Hair Care Industries

Formaldehyde

The main concern of formaldehyde is its potential to react with hydrochloric acid to form bis (chloroinethy 1) ether, a known carcinogen. The irritant properties of formaldehyde affect the mucous membrane surfaces of the upper respiratory tract, the eyes and the exposed surfaces of the skin. The characteristic odour of the chemical is detectable by most people at concentrations as low as 1 ppm. Mild irritation of the eyes, nose and throat are observed at 2 to 5 ppm and is intolerable at levels in excess of 25 ppm. Besides, there is a potential for development of sensitization dermatitis [6].

Additionally, formaldehyde is known to be a potent sensitizer and irritant. In people who are allergic to the substance, it can result in allergic responses, contact dermatitis, and irritating dermatitis. The frequency of formaldehyde allergy among patients with suspected allergic contact dermatitis was examined in a study that was published in Contact Dermatitis [6]. Exposure to formaldehyde, both direct and prolonged, can cause severe health issues and potentially lead to death. It is recognized as a human carcinogen by numerous organizations and can negatively affect the endocrine system, as well as having mutagenic or teratogenic effects. Formaldehyde plays a significant role in the global economy due to its unique chemical properties and widespread use in both the medical field and various industrial sectors. The production of synthetic braids and hair products has been associated with the chemical component formaldehyde. It can be released from the formaldehyde-releasing agents (FRAs) utilized in these products, where it is predominantly used as a preservative [7]. However, formaldehyde (HCHO) is classified as a persistent organic pollutant (POPs) and is known to be harmful. The extruded strands are stretched or drawn to align the polymer strands and improve strength and tensile properties. The drawn filaments may undergo a texturing process to add crimps or waves to give the braids a more realistic appearance.

Formaldehyde is employed in synthetic hair manufacture mainly as resins. The formaldehyde resins including urea-formaldehyde resin and phenol-formaldehyde resins are used as adhesives and binders. It serves as a preservative and fixative to enhance the shape and structure of synthetic fibers. Formaldehyde is also used in the bonding of hair fibers together enhancing durability and longevity of the synthetic hairs. The potential health risks associated with synthetic braids have raised concerns about the safety of these products and the need for stricter safety standards. Several studies have investigated the chemical components in synthetic braids that irritate. An investigation of the prevalence of allergic contact dermatitis to formaldehyde among hairdressing apprentices was conducted and the results were published in the Journal of the American Academy of Dermatology[8]. The findings showed that formaldehyde was a typical allergen and that contact with formaldehyde-containing hair products was linked to the occurrence of allergic and irritating skin reactions. According to the research, formaldehyde is one of the most prevalent allergens, and those who have used formaldehyde-containing items, such as hair products, have seen positive patch test results.

Thioglycolate (ATG)

Ammonium thioglycolate also known as perm solution, plays a pivotal role in braid styling by acting as a reducing agent, which softens the braid. This allows the alteration of the synthetic hair's structure making it manageable for reshaping and styling to create certain hair textures and styles that mimic natural hair.

ATG allows manufacturers to produce a variety of styles and looks during the process of curling. Ammonium Thioglycolate (ATG) is a chemical compound commonly used in hair processes, including perming and relaxing treatments. While it is generally considered safe when used properly, some individuals may develop allergic contact dermatitis as a result of exposure to ATG [9]. Numerous studies have looked into how irritant ATG might be. The incidence of ATG allergy among patients with suspected allergic contact dermatitis was investigated in a study published in South [10]. ATG was found to be one of the most prevalent allergens, particularly those used in braids, experienced irritation [11]. ATG has also been linked to some skin responses. The causes of ATG induced contact hypersensitivity were examined in a study that was published in the Journal of the American Academy of Dermatology. According to the study, exposure to ATG can trigger immunological reactions that cause skin inflammation, redness, itching, and, in more extreme circumstances, blistering or leaking of the skin [11] (Gerberick *et al.,* 2010).

Lubricating, Sizing and Antistatic Agents

Lubricating agents and antistatic substances are routinely used to reduce friction and control static electricity during drawing and texturing. These materials make it easier to handle and prepare braids. The constantly patterned strands are cut to the required lengths to create individual braids. Braids may undergo a sizing treatment after being cut, during which a protective covering is placed to make handling easier, prevent fraying, and enhance aesthetic appeal. Sizing agents are added chemically to the braids to provide lubrication, reduce tangling, and improve manageability. Formaldehyde plays a role as a sizing agent by contributing to the longevity and appearance of braids, serves as an antimicrobial agent, preservative and stabilizer for texture and color Polymers that create films or coatings made of silicone are two examples. Complementary substances like colors, pigments, or scents may be added for aesthetic purposes; however, they may expose some people to irritability or allergic reactions.

Braiding Hair, Professional Cosmetology and the Beauty Industry

Synthetic braids come in a variety of styles, colors, and textures, making them a versatile choice for people of all ages and backgrounds. They offer a low-maintenance alternative to traditional hairstyles and can be styled in a variety of ways. From box braids to twists, synthetic braids have become a staple in the beauty industry. From a global perspective, synthetic braids have become a popular choice for many women in African countries, where braids are a traditional hairstyle. In addition, synthetic braids have gained popularity in other parts of the world, such as North America and Europe, where they are often worn as fashion statement [12]. The production of synthetic hair often involves the use of harsh chemicals and can have negative environmental impacts. Additionally, many synthetic braids are produced in countries with poor labor standards, leading to exploitation and poor working conditions for factory workers. Furthermore, the cultural appropriation of synthetic braids has become a controversial topic. Many argue that the style has been appropriated from the Black culture without proper credit or acknowledgment.

It is important to be mindful of the cultural significance of hairstyles and to respect their origins. In Kenya, synthetic braids share the same popularity. Their convenience and versatility make them an attractive option. However, there has been some controversy surrounding the use of synthetic braids in Kenya. Some argue that the prevalence of synthetic braids is contributing to a loss of traditional Kenyan hairstyles and cultural identity. Additionally, there are concerns about the quality of some synthetic braids, which can lead to hair damage and hair loss if not installed and maintained properly. Despite these concerns, synthetic braids remain a popular choice for many Kenyan women. They offer a convenient and affordable option for those looking for a low-maintenance hairstyle. As with any hairstyle, it is important to consider the potential risks and to take proper care to avoid damage to the hair and scalp.

Experimental

Objectives

The current study aimed to determine and quantify the probable presence of formaldehyde and ammonium thioglycolate (ATG) allergens in commercial synthetic braiding hair sold in sold in selected cosmetic beauty shops in Kisii Town, Kenya.

Sampling

Sampling Sites

The sampling technique used in the current study was random sampling. This involved selecting (6) different types of hair braiding brands from two particular synthetic brands from selected cosmetic beauty shops in Kisii town. Random sampling involved in-person purchasing of the samples from the individual cosmetic shops. From each shop, (1) sample was purchased, ensuring all the (6) samples were purchased from different locations. The outlets included retail shops, open markets, and beauty supply stores.

Coding of the Hair Braiding Samples

The obtained commercial hair braids were coded as: - (i) alpha (ii) omega.

Hair Braiding Samples Preparation

The study explored the possibility of the concentration of formaldehyde and ammonium thioglycolate (ATG) to differ depending on the section of the braid. The braid sections used in the study were the center section, outer layers, and end/edges.

Map of Sampling Area

Samples were obtained from Kisii town, which is the administrative and commercial Centre of Kisii County that forms one of the forty-seven counties of Kenya. According to the 2019 Kenya Population and Housing Census, Kisii County registered a total population of 1,266,860 inhabitants out of which 661,516 (52.3%) were females. Map of Kisii County is shown in figure 1[13]: -

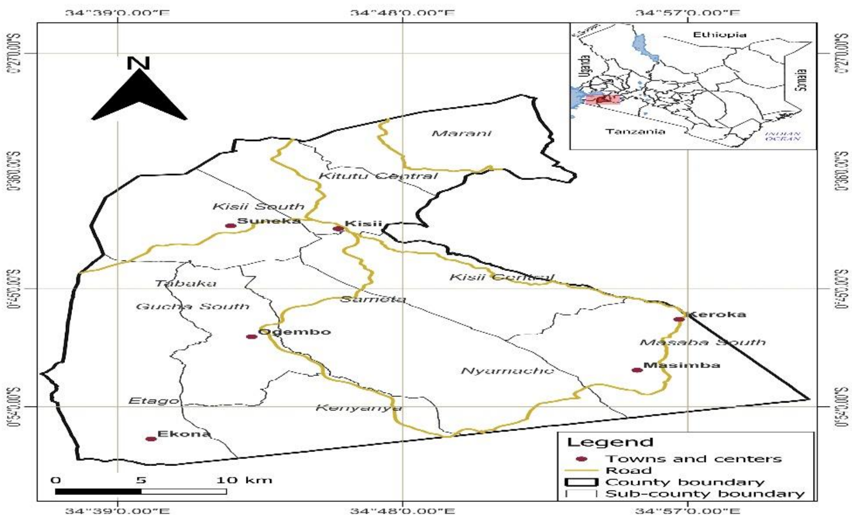

Figure 1: Map of Kisii County, Kenya

Preparation of Reagents

Preparation of Tollens Reagent

A volume of 10 mL of 0.1 M of silver nitrate ($AgNO_3$) was put in a clean beaker. 10 mL of concentrated ammonia solution was added to the beaker and stirred. 10 mL of 0.1M of sodium hydroxide solution was carefully added to the silver ammoniate solution while stirring. This formed the Tollens' reagent, which was colorless.

Preparation of Standard Solution

A volume of 0.37 mL of purity (37%) concentration of stock formalin solutions was added to 100 mL of distilled water providing 100 ppm of stock standard solutions. Thereafter, (5) various concentrations of stock standard solutions were obtained by serial dilutions to obtain formaldehyde solutions= (10ppm,30 ppm,50ppm,70ppm &90ppm). The prepared solutions were thereafter used to determine the maximum absorbance.

Procedure for Determining the Presence of Formaldehyde

Pieces of braids from all the brands were cut into small pieces, placed into a test tube, and labeled accurately.10 mL of methanol was added into each labeled test tube and left to soak for 30 minutes. A filter paper was used to filter the liquid extract to separate it from the samples. A few drops of Tollens' reagent were added to the filtrate from every sample and the colour change observed.

Procedure for Determining the Presence of Ammonium Thioglycolate

Pieces of braids from all the brands were cut into small pieces, placed into a test tube, and labeled accurately. 10 mL of methanol was added into each labeled test tube and left to soak for 30 minutes. A filter paper was used to filter the liquid extract to separate it from the samples. A few drops of silver nitrate were added to the filtrate of every sample and the color change observed.

Testing for Formaldehyde in Braids Using UV-Vis Spectroscopy

The liquid extract in both alpha and omega samples was filtered to remove any particles or impurities that may interfere with the UV-Vis spectrophotometry measurement. Standard solutions of formaldehyde were prepared which included c= (10ppm,30ppm,50ppm,70ppm&90ppm concentrations). The spectrophotometer was set to the specific wavelength at which formaldehyde absorbs ultraviolet light (λ=353 nm), a blank solution was prepared, and its absorbance measured. A small amount of the filtered sample solution of alpha sample from the center section was placed in a 1 cm cuvette and placed in the spectrophotometer. The fourth step was repeated for both the outer layer and the edges section. The measurement was then recorded and the same procedure was repeated for the filtered sample solution of omega sample and absorbance readings recorded. The calibration curve was then used to convert the absorbance reading of the sample into a concentration of formaldehyde for both alpha and omega samples. The results were then analysed and the concentration of formaldehyde in the braids was calculated.

Data Processing and Analysis

Qualitative Analysis Methods

Colour changes that occurred:

Ammonium Thioglycolate (ATG)

Filtrates samples v=20 mL, each from the two hair braids were placed into test tubes. Thereafter droplets of silver nitrate were added to each of the (18) samples in the test tubes. Chemical interactions between ammonium thioglycolate and silver nitrates yields a dense, insoluble silver thioglycolate precipitate that is uniquely yellowish white in colour.

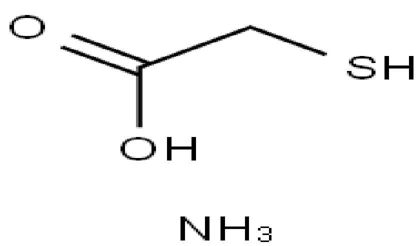

Figure 2: Structural formula - ammonium thioglycolate

Formaldehyde (Tollens' Test/Mirror Test)

The colourless Tollens' reagent prepared in (section 2.4) was used to test for the presence of formaldehyde in the (18) hair braiding samples. Formaldehyde acts as a strong reducing agent, reducing silver ions (Ag^+) in the mixture to metallic silver (Ag), which coats the clean glass walls of the test tube forming a silver mirror. Figure 3 shows the structural formula of formaldehyde.

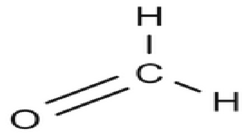

Figure 3: Structural formula of formaldehyde

Quantitative Analysis

Descriptive Statistics:

Mean concentration of formaldehyde:

In Alpha sample

Mean (X̄) =n∑i=1nXi (1)

(0.8+0.9+0.7)\3=0.8

In Omega sample

Mean (X̄) =n∑i=1nXi (2)

(0.5+0.7+0.4)\3=0.5

The mean provided a measure of central tendency, indicating the typical concentration of formaldehyde within each brand. Knowing the average concentration helped understand the typical level of formaldehyde present, providing a baseline for comparison.

Variability Assessment

Standard Deviation: Measures the dispersion or variability of data points from the mean. It indicates how consistent or variable formaldehyde concentrations are within each brand. A higher standard deviation suggests greater variability.

$$\sqrt{\frac{\sum(Xi-X)^2}{N}} \qquad (3)$$

Where:

- N is the number of observations,
- Xi is each observation,
- X is the mean

Alpha Sample

$=\sqrt{(0.01+0.00+0.01)} \div 3$

$=0.0816$

A standard deviation of 0.0816 suggested that formaldehyde concentrations within alpha sample braids were relatively consistent. The low standard deviation indicates that the concentrations were close to the mean, implying less variability.

Omega Sample

Dsquared=$\sqrt{(0.01+0.04+0.00)} \div 3$

$=0.1291$

The standard deviation of 0.1291 suggests a relatively higher variability in formaldehyde concentrations within omega sample braids compared to alpha sample. The concentrations are close to the mean, but the higher standard deviation implies a bit more spread or variability around the mean, indicating a lower level of uniformity in the product.

Comparative Assessment Alpha Vs. Omega Samples:

Comparing the two: 0.0816 (alpha sample) < 0.1291 (omega sample):
Therefore, alpha sample braids have a lower standard deviation, suggesting that formaldehyde concentrations are more consistent within alpha sample compared to omega sample. This indicates that alpha sample braids exhibit less variability in formaldehyde concentrations around the mean, indicating a higher level of uniformity in the product.

Comparison with Standards

The concentrations of formaldehyde found in both alpha sample and omega sample braids were compared to industry standards. According to the Multidisciplinary Digital Publishing Institute (MDPI) and US Cosmetic Ingredient Review Expert Panel, the acceptable limit for formaldehyde in hair products is 20 ppm. The results significantly exceed this limit, raising concerns about potential health risks associated with the use of these synthetic braids. The graph in figure 2, shows a calibration curve of absorbance against concentration. From this curve, the concentrations of formaldehyde were established.

Results and Discussion

Identification of Ammonium Thioglycolate (ATG)

There were no observable colour changes in the addition of silver nitrate to the samples of the braids. This consequently eliminated the quantitative part of the same.

Identification of Formaldehyde

The absorbance was determined using a UV-Vis spectrophotometer. The analysis revealed the presence of formaldehyde in both alpha and omega sample synthetic braids.

Calibration Curve

The results indicating a calibration curve for formaldehyde is shown in table 1 and figure 2: -

Table 1: Formaldéhyde Solution Concentrations Vs. Absorbance

Standard Solutions Concentration [Ppm]	Absorbance
blank	0.000
10	0.025
30	0.092
50	0.163
70	0.238
90	0.312

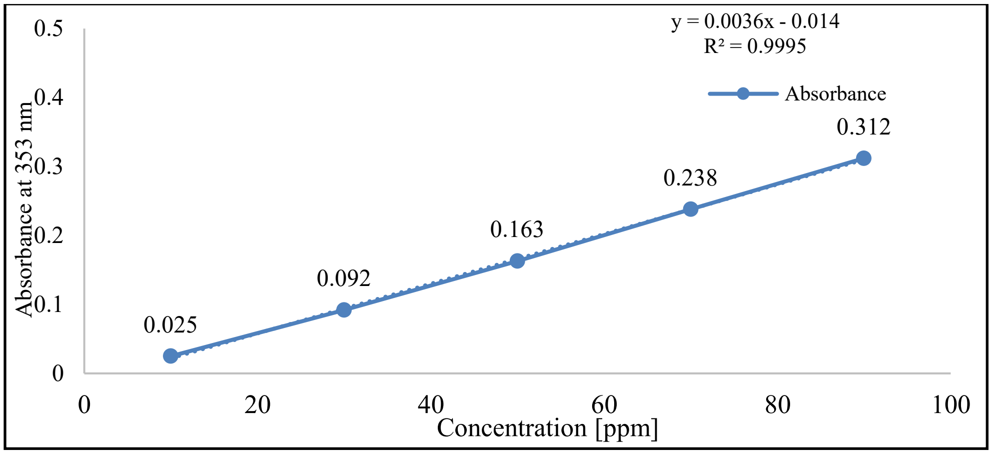

Figure 4: Calibration curve for formaldehyde

Table 2: Formaldehyde concentrations in Synthetic Braids Braid Types

Braid	Section	Absorbance	Concentration [ppm]
Alpha	Center	0.295	80
	Outer layer	0.350	90
	Ends/edges	0.238	70
Omega	Center	0.126	50
	Outer layer	0.238	70
	Ends/edges	0.008	40

From figure 2 & table 2, the results show variations in concentration within a single braid can occur due to several reasons, including:

- *Center Section:* The central part, being closer to the manufacturing core, may have absorbed a significant amount of formaldehyde during production.
- *Outer Layers:* The outer layers might have been exposed more to the manufacturing environment, leading to a slightly higher concentration.
- *Ends/Edges:* The ends of the braid may have had less exposure during manufacturing or could have undergone some treatment that reduced formaldehyde absorption.

Conclusions

The results show that individual synthetic braids sold in consumer beauty shops in Kisii town showed varying quality. The Alpha synthetic braids are of superior quality compared to Omega. Furthermore, the assessment of variability within each brand, as indicated by standard deviations, revealed that alpha sample braids had a lower standard deviation (0.0816) compared to omega sample braids (0.1291). This suggested that formaldehyde concentrations in alpha sample braids are more consistent, with less variability around the mean, while omega samples braids exhibit a slightly higher degree of variability. The synthetic braiding hair production process influenced the distribution of formaldehyde allergen within the braiding hair i.e. elevated amounts were detected on the outer layers of the braids and least amounts on the ends/edges. Traces of formaldehyde detected reduces the overall quality of the synthetic braids sold in cosmetic beauty shops in Kisii town. These values exceeded the limits of 20 ppm set by the Multidisciplinary Digital Publishing Institute (MDPI) MDPI and US Cosmetic Ingredient Review Expert Panel.

Conflict of interest

The authors declare no competing interest.

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Declaration on the Use of Artificial Intelligence

The authors confirm that no artificial intelligence software was used.

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